POGIL: Describing Motion

Purpose
To become familiar with the terms we use to describe motion

Part 1, Definitions
The following shows a list of terms we use to describe motion and their definitions. Read them carefully and then answer the questions that follow.

- position – the location of an object
- instantaneous speed – how fast an object is moving at a particular instant in time
- instantaneous velocity – how fast an object is moving at a particular instant in time *and* the direction of the object's motion
- acceleration – a change in velocity

Critical Thinking Questions

1. What is the difference between a speed and a velocity?

2. For each of the following quantities, state whether this is a description of a position, a speed, a velocity, or an acceleration.
    a. a truck cruises down the highway at 100 km/h

    b. a truck cruises down the highway at 100 km/h toward the east

    c. a truck increases its speed from 20 m/s to 40 m/s

    d. a truck is 300 km east of Culver, Indiana

    e. a truck slams on its brakes and slows down at a rate of 5 m/s each second

3. The chart below shows several descriptions of motion. For each one, indicate the following:
   - whether the object has a constant or changing speed
   - whether the object has a constant or changing velocity
   - whether the object is accelerating or not accelerating

Description of Motion	Is the speed constant or changing?	Is the velocity constant or changing?	Is the object accelerating or not accelerating?
A sprinter runs a race starting from rest and reaches a top speed of 10 m/s			
A race car travels along a straight section of a race track at a constant 90 m/s			
A cyclist travels around a curve at a constant 13 m/s			

4. Study the third column of the chart in question #3. There are two things that can be changing during an object's motion for it to be accelerating. What are they?

Part 2. Definitions

Now we'll look at how to calculate the average values (as opposed to instantaneous values) of an object's speed and acceleration. Read each definition carefully, look at the example calculation, and answer the questions that follow.

average speed – the distance an object travels divided by the time the object takes to travel that distance. The unit of measurement is a distance unit divided by a time unit. The average speed can be thought of as the average of all the instantaneous speeds during the motion.

An object that travels 20 m in 5 s has an average speed of:

$$\text{average speed} = \frac{\text{distance}}{\text{time}} = \frac{20\text{ m}}{5\text{ s}} = 4\text{ m/s}$$

This means that the object traveled an average of 4 m during each second of the motion. Notice that if the speed during the motion is constant then the average speed equals the instantaneous speed during the entire motion.

average acceleration – the change in velocity during the motion divided by the time it takes the velocity to change. The unit of measurement is a unit of speed divided by a time unit. For example, suppose an object moving at a velocity of 5 km/h north increases its velocity to 20 km/h north in 20 s. The average acceleration is:

$$\text{average acceleration} = \frac{\text{change in velocity}}{\text{time}} = \frac{20 \text{ km/h} - 5 \text{ km/h}}{20 \text{ s}}$$

$$= \frac{15 \text{ km/h}}{20 \text{ s}} = 0.75 \text{ km/h/s} = 0.75 \text{ km/h} \times \text{s}$$

This means that during each second of the motion, the velocity changed by an average of 0.75 km/h. As a second example, suppose an object decreases its velocity from 10 m/s to 2 m/s in 10 s. The average acceleration is:

$$\text{average acceleration} = \frac{\text{change in velocity}}{\text{time}} = \frac{2 \text{ m/s} - 10 \text{ m/s}}{10 \text{ s}}$$

$$= \frac{-8 \text{ m/s}}{10 \text{ s}} = -0.8 \text{ m/s/s} = -0.8 \text{ m/s} \times \text{s} = -0.8 \text{ m/s}^2$$

This means that during each second of the motion, the velocity changed by and average of −0.8 m/s. Similar to the average speed, the average acceleration can be thought of as the average of all the instantaneous accelerations during the motion. If the velocity changes at a constant rate, then the average acceleration is equal to the instantaneous acceleration.

Calculations

5. For each of the following descriptions of motion, calculate the object's average speed, *including the correct units*.
    a. Mr. Cook can bike from his home to the Culver campus, a distance of approximately 2.4 km, in 0.10 hours.

    b. Mr. Cook can drive from his home to the Culver campus in 2 minutes and 45 seconds.

    c. Light can travel from the sun to the Earth (93,000,000 miles) in 8 minutes.

6. For each of the following descriptions of motion, calculate the average acceleration, *including the correct units.*
    a. A car with a powerful engine can go from 0 km/h to 100 km/h in 8 s.

    b. A child on a tricycle slows down from 4 m/s to 1 m/s in 5 s.

    c. A ball rolling up a hill goes from 3 m/s up the hill to 3 m/s down the hill in 6 s.

    d. An athlete runs in a straight line at a constant speed of 6 m/s for 10 s.

7. In the units for acceleration, why are there two time units?

Conclusions

For your conclusions, write a short paragraph in clear, complete sentences that addresses the following questions:

- What is the difference between an *average* quantity and an *instantaneous* quantity?
- How do we describe how fast an object is moving?
- How do we describe the rate of change of the rate at which an object moves?
- What are the two ways that an object can accelerate?